Evaluation and Selection of Technologies for the Removal of RDX from an Industrial Wastewater Stream

David B. Gent, Ph.D
US Army Engineer
Research and Development Center
Vicksburg, MS

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
07 MAY 2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Evaluation and Selection of Technologies for the Removal of RDX from an Industrial Wastewater Stream	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army Engineer Research and Development Center,3909 Halls Ferry Road,Vicksburg,MS,39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at the NDIA Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition held 4-7 May 2009 in Denver, CO.

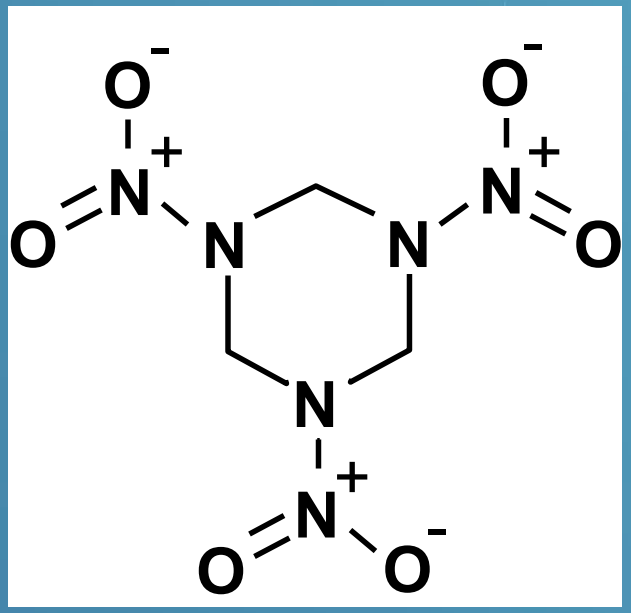
14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**20**	

What is RDX?

- Nitramine explosive
- Listed wastes under subpart D of RCRA



hexahydro-1,3,5-trinitro-1,3,5 triazine

Environmentally Relevant

- Army Ammunition Plants
- Demilitarization sites

Solubility at 20°C ~ 40 mg/L

Density at 20°C 1.82 g/mL

Royal Demolition eXplosive
Research Department Explosive
cyclonite or hexogen

RDX in Water

- RDX production results in saturated or supersaturated RDX process wastewater (excess of 40 mg/L)
- EPA Lifetime health advisory limit for RDX in drinking water is 2 µg/L

Problem

Large volumes of water with RDX exit production area

HSAAP has a large industrial wastewater treatment plant

but

RDX is difficult to treat with aerobic biological processes

Objective

Find technologies that can reduce concentration of RDX before entering the waste treatment system

Government/Industry Team

PM
Joint Services
(Funding and Management)

PM Joint Services

US ARMY RDECOM

READY RELIABLE LETHAL

U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT CENTER ERDC

BAE SYSTEMS

STEVENS Institute of Technology

NDCEE National Defense Center for Energy and Environment

SAIC From Science to Solutions

Diversified Technologies Services DTs INC.

MALCOLM PIRNIE

Goal: Assess a broad scope of technologies and approaches to mitigating RDX wastewater at HSAAP

Processes that destroy RDX

Non Destructive

- Granular Activated Carbon
- Reverse Osmosis

Destructive

- Anaerobic biological processes
  - Anaerobic fluidized bed
- Zero-Valiant Iron (ZVI)
  - Filter or mixed in batch slurry
- Bi-metallic Particles - mixed in batch slurry
- Ultraviolet Oxidation
- Alkaline Hydrolysis
- Electrochemical - direct electrolytic

Treatment Issues in Production Facilities

Safety

Iron & glass sensitize RDX crystals

All electrical systems must be explosion proof

Process

High RDX concentrations in some process water

Large volumes of water used (Safety)

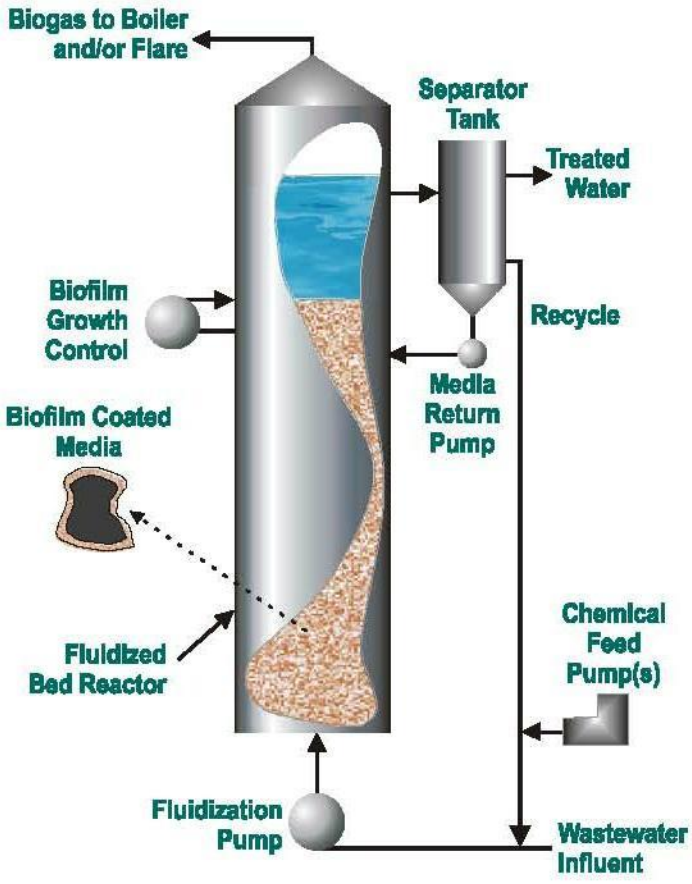
Granular Activated Carbon (GAC)

- GAC - good adsorbent medium
- High surface area to volume ratio
- 1 gram = 1,000 m^2 (surface area)
- accumulates large number of contaminant molecules

- GAC Regeneration
  - Thermal
  - Solvent
- Removed as Hazardous Waste
  - DOT Class 1 explosive hazard > 10% by mass
- Expensive – cost increase > 2X in last 5 years

Anaerobic Fluidized Bed

- Installed McAlester AAP
  treats "pink water" from load & pack operations (TNT/RDX/HMX)
- Replaces GAC sorption



cost of treatment

Reverse Osmosis (RO)

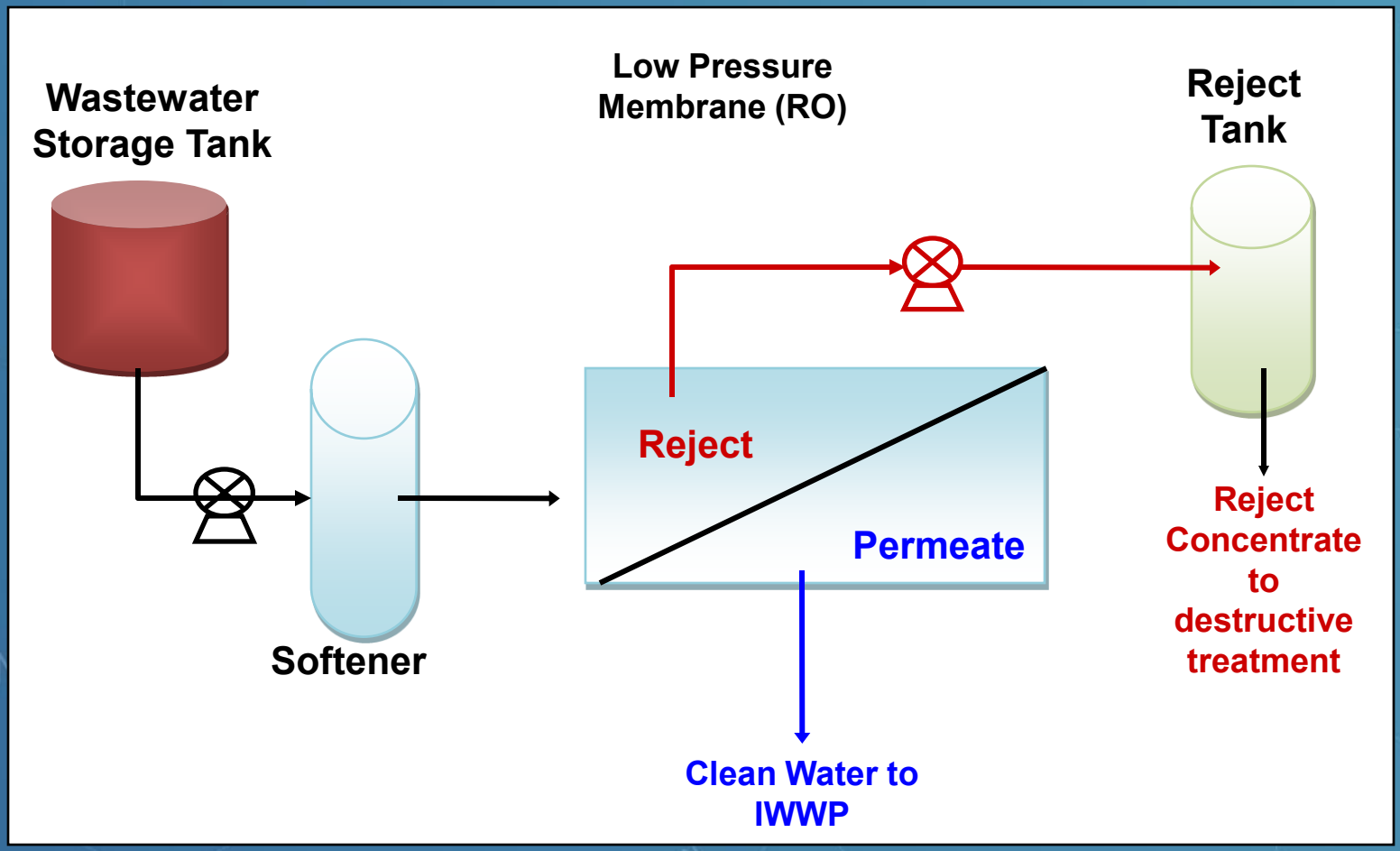
Benefits

- Low operating and maintainance cost
- PLC automated operations
- Reduces RDX contaminant mass loading to IWWP

Drawbacks

- Potential interferences (contaminants): Cl, F, Nitrates, Sulfates, Nitrites, Ca, Mg, Na
- Membranes must be replace periodically < 1 per year

Reverse Osmosis (RO)



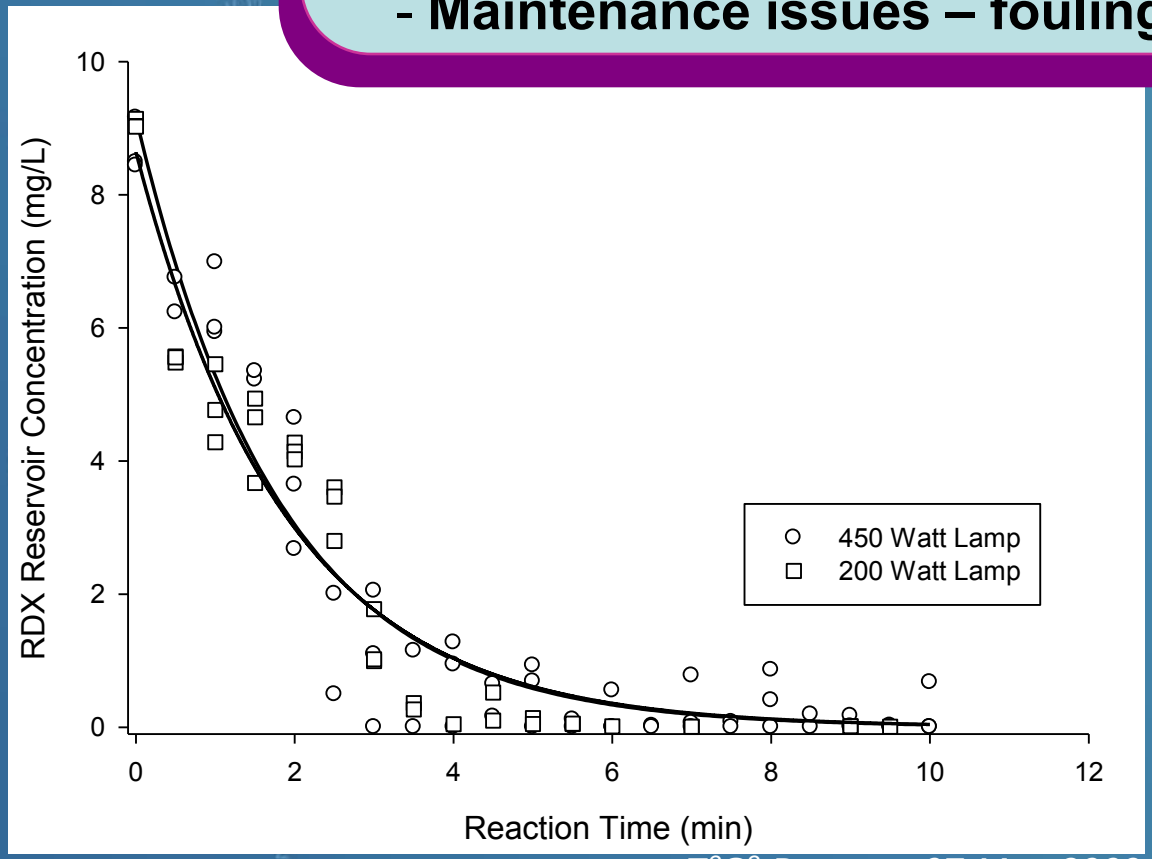
Ultraviolet Oxidation

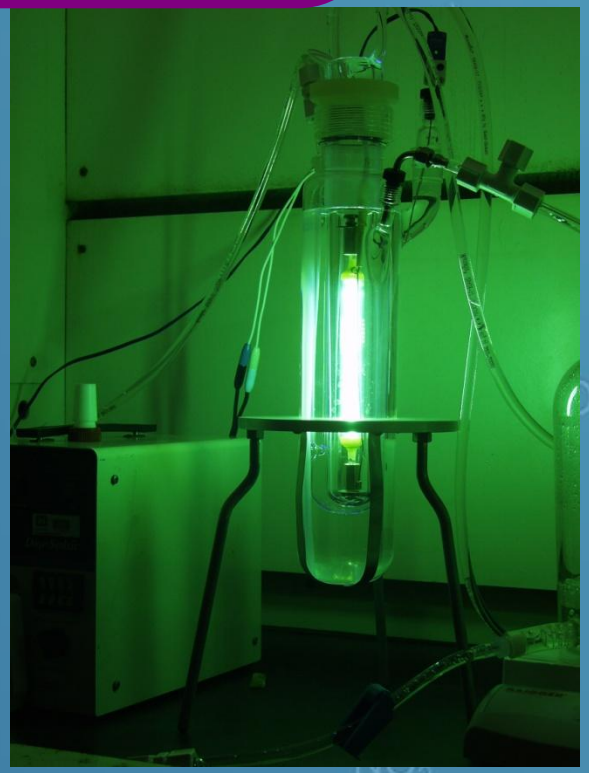
Benefits

- Very fast. Half life on the order of 1 min

Drawbacks

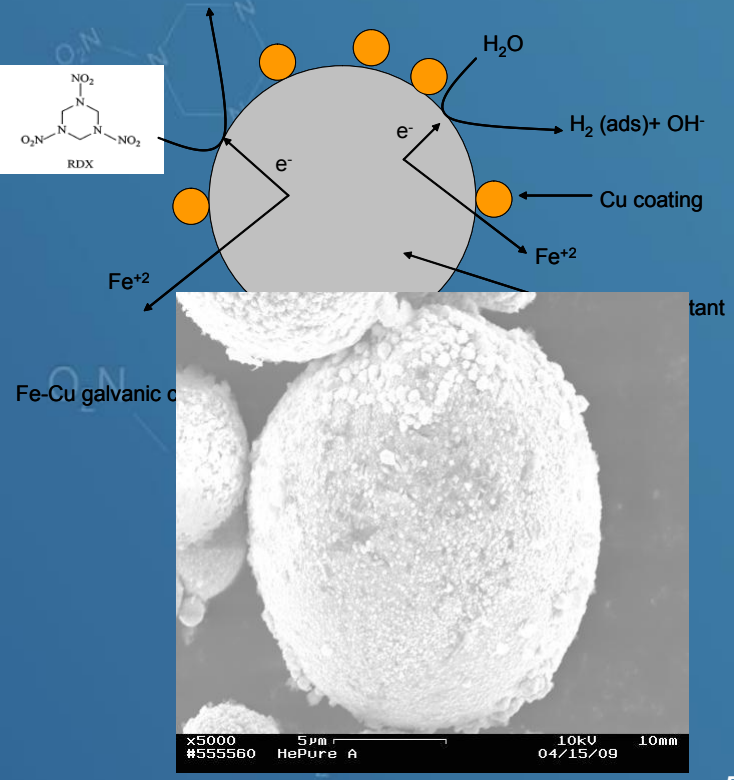
- High energy per unit treated
- Uses glass jackets
- Maintenance issues – fouling

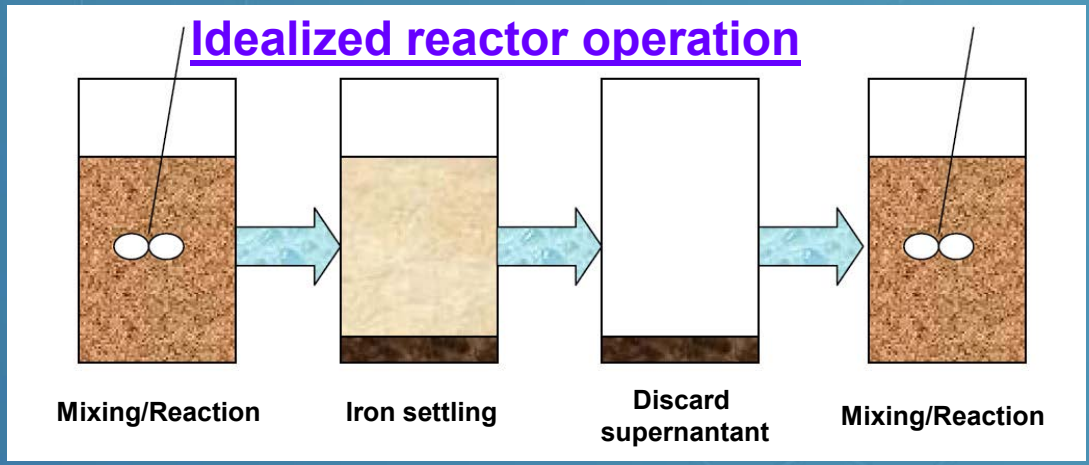




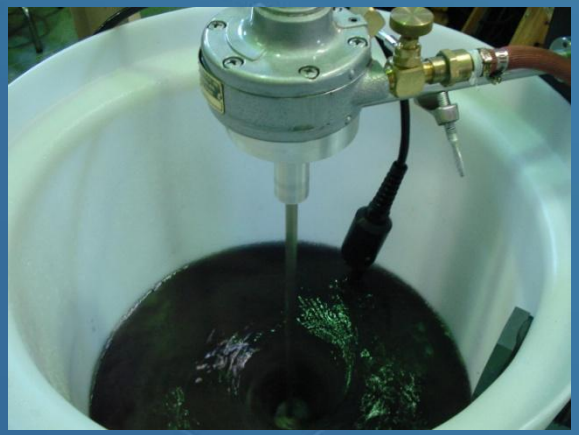
Bi-metal ZVI

Similar processes
Small particles mixed in batch slurry with process water
Bi-metal – enhances the reductive capabilities of ZVI by partially coating iron particles with Cu





Bi-metal ZVI



Benefits

Fast half life - 5 min

Complete degradation of nitrosamines derivates

Drawbacks

Labor intensive, although process can be made fully automated

Requires adjusting pH to 4 - 4.5. Final pH between 5.6 and 6.5

Replacement of bi-metallic particles every 12 cycles

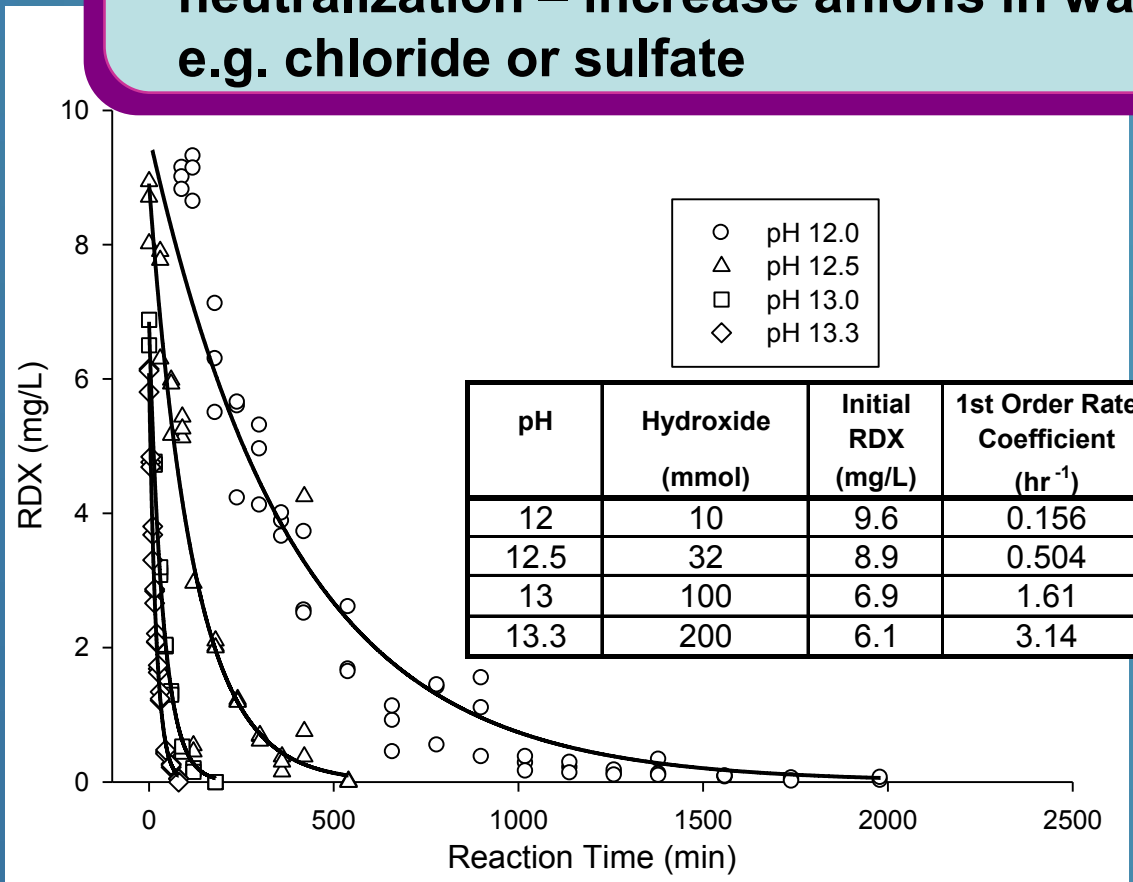
No commercial source of bi-metal material. Simple electroless plating process.

Alkaline Hydrolysis

Hydrolysis - efficient, cheap, and easy to implement
Good for low flow rates or low volumes

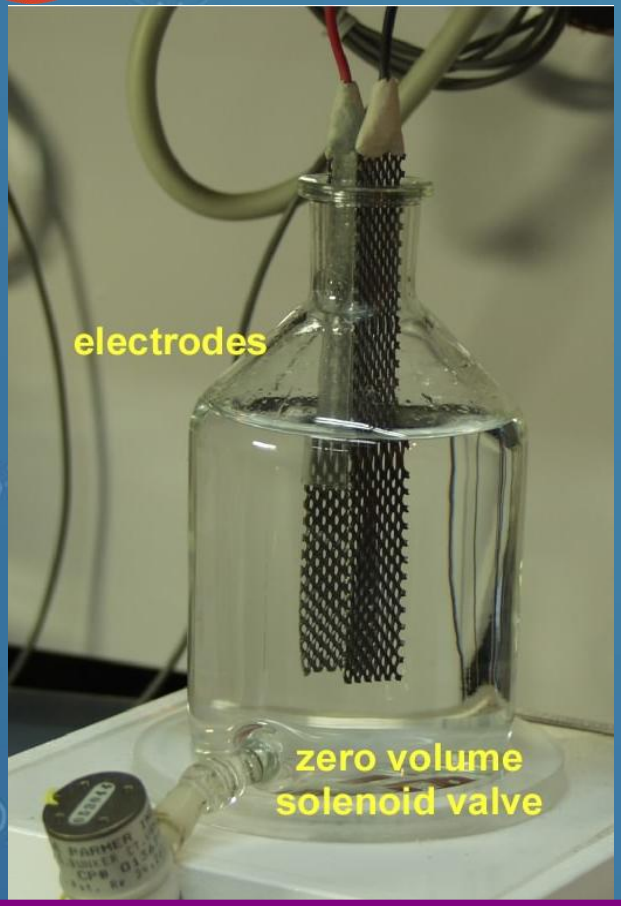
Drawbacks –

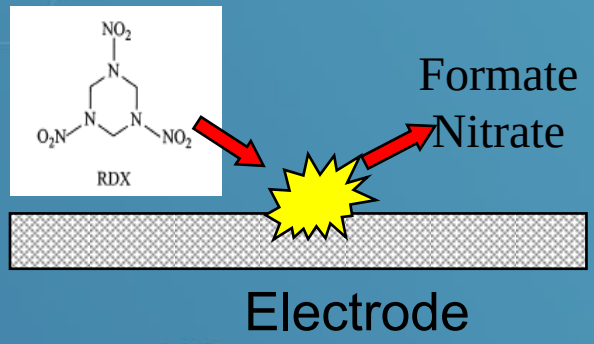
chemical handling safety
neutralization – increase anions in water
e.g. chloride or sulfate



pH	Hydroxide (mmol)	Initial RDX (mg/L)	1st Order Rate Coefficient (hr^{-1})	Half Life (hr)
12	10	9.6	0.156	4.4
12.5	32	8.9	0.504	1.4
13	100	6.9	1.61	0.4
13.3	200	6.1	3.14	0.2

Direct Electrochemical Reduction





Benefits

- No chemical additive required
- Batch or flow through systems
- Electrical costs
  - less or similar to chemical costs

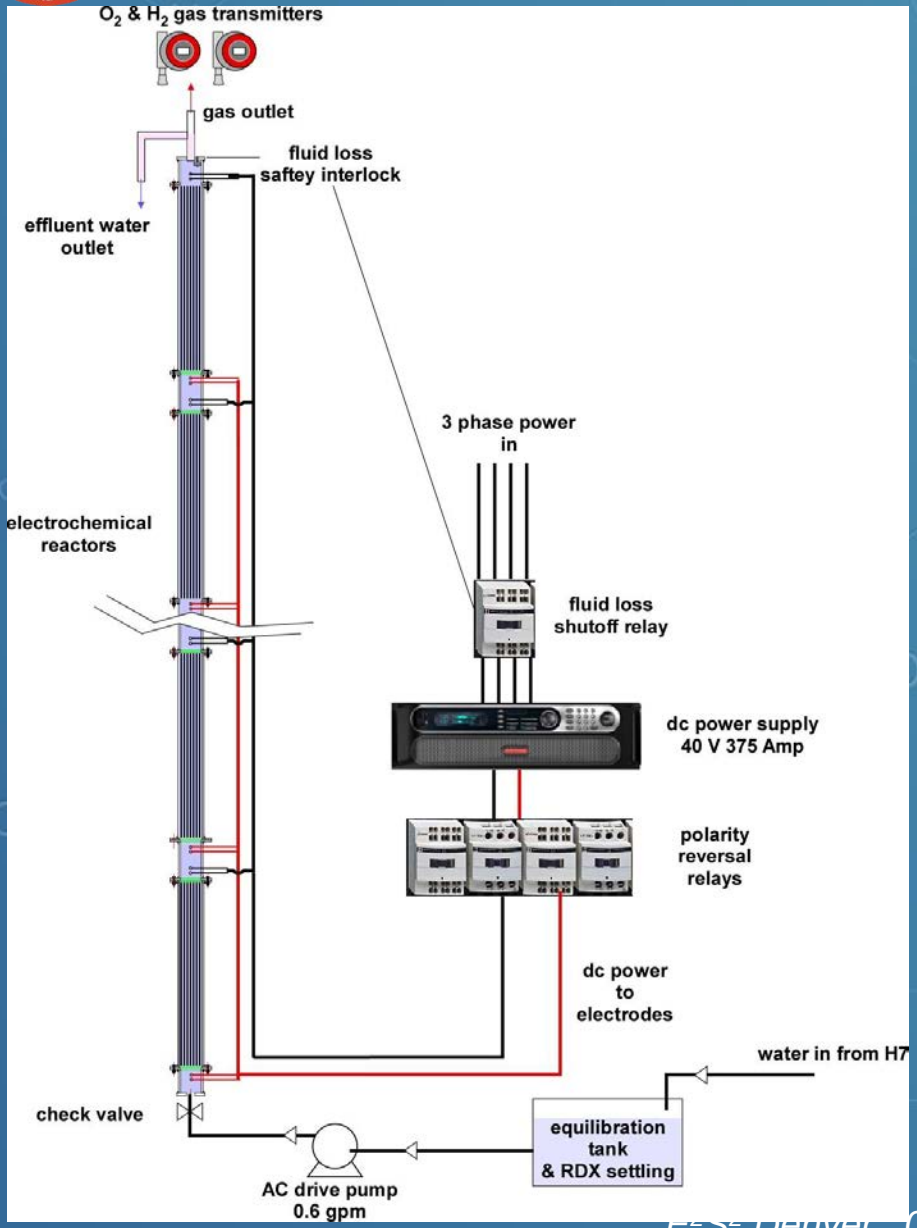
Potential disadvantages

- Not demonstrated at full-scale
- Electrode costs
- Electrode life

System design parameters

- mass transfer
- current density

Conceptual Drawing
Modular 5-stack Reactor Unit



Major components

- reactor vessels
- electrodes
- polarity reversal relays
- variable flow peristaltic pump

Safety features

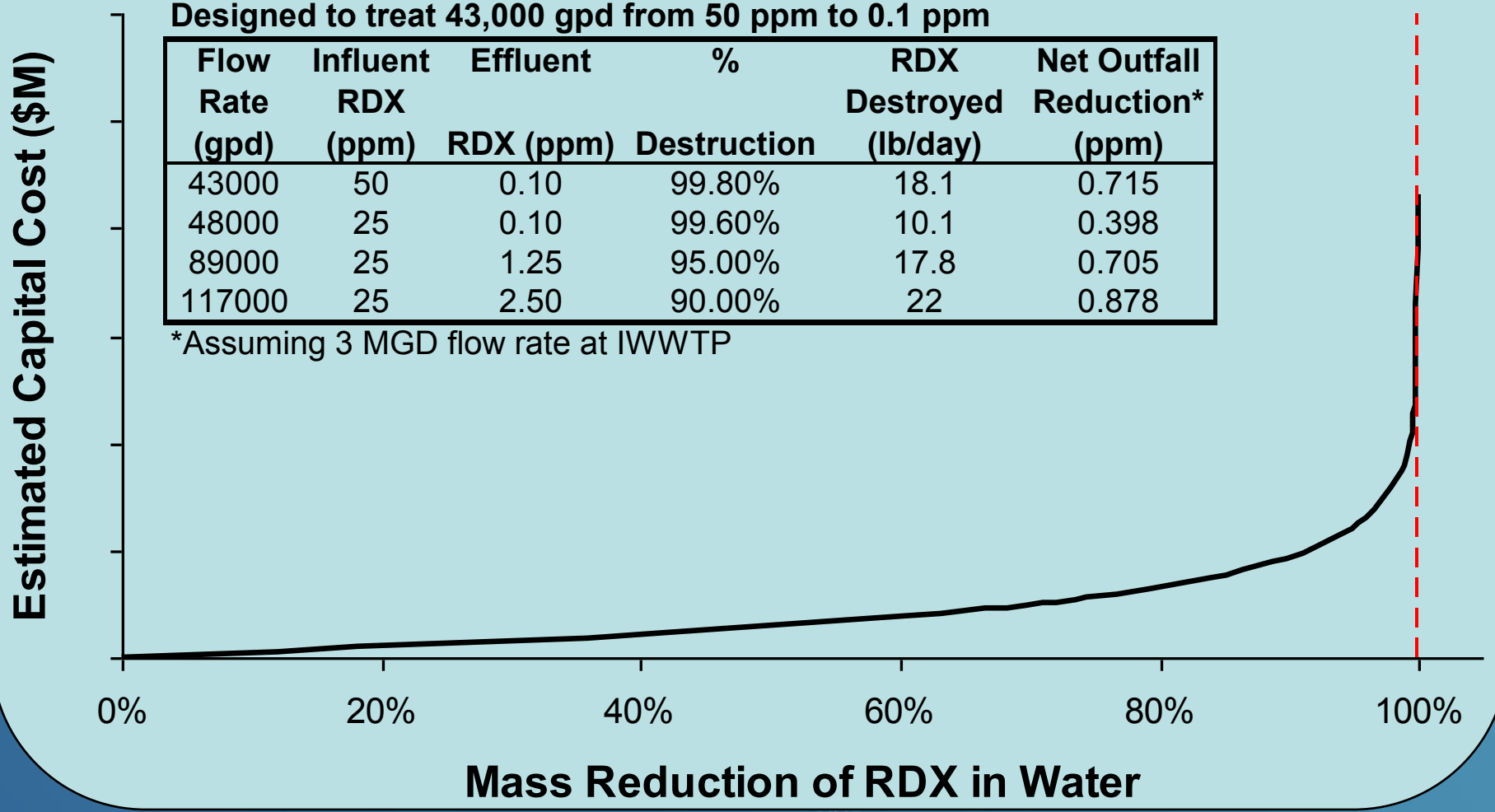
- submitted for safety approval
- float switches
- check valves
- gas sensors
- power interlock
- consulting with BAE Engineering

Capital Requirement

Original Pilot Design: 250 Reactor Elements
Designed to treat 43,000 gpd from 50 ppm to 0.1 ppm

Flow Rate (gpd)	Influent RDX (ppm)	Effluent RDX (ppm)	% Destruction	RDX Destroyed (lb/day)	Net Outfall Reduction* (ppm)
43000	50	0.10	99.80%	18.1	0.715
48000	25	0.10	99.60%	10.1	0.398
89000	25	1.25	95.00%	17.8	0.705
117000	25	2.50	90.00%	22	0.878

*Assuming 3 MGD flow rate at IWWTP



Ultimate goal

- **Build or install full and pilot-scale systems at HSAAP**

  - **Reverse Osmosis**
  - **Electrochemical**
  - **Fluidized bed bio-reactor system**
  - **Bi-metal**

Questions?